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Self Driving Car Using LIDAR Sensor

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A B S T R A C T

Self-driving cars rely on advanced sensing and perception technologies to navigate complex road environments without human intervention. Among these technologies, LiDAR (Light Detection and Ranging) plays a critical role by providing high-resolution of a vehicle's surroundings. By emitting laser pulses and analyzing the reflected signals, LiDAR systems generate precise accurate object detection, distance estimation, and environmental modeling. This prototype demonstrates the working principle of LiDAR-based navigation and proves that accurate sensing significantly improves safety and performance in autonomous vehicles. The project highlights the potential of LiDAR technology in future intelligent transportation systems and encourages further research in autonomous mobility

Keywords:

- LiDAR (Light Detection and Ranging)
- Laser Pulses
- Distance Measurement
- Obstacle Detection
- Autonomous Navigation

1. Main Text

Urban transportation faces growing challenges such as traffic congestion, rising accident rates, human driving errors, and the need for safer and more efficient mobility solutions. To address these issues, self-driving car technology offers an intelligent and automated approach to modern transportation. A self-driving car uses advanced sensors and computing systems to perceive its surroundings, make decisions, and operate without human control. Among these sensors, LiDAR plays a crucial role. LiDAR (Light Detection and Ranging) continuously scans the environment using laser pulses and generates a detailed 3D map that helps the vehicle detect obstacles, identify road boundaries, and measure distances with high accuracy. This enables the vehicle to navigate safely even in complex road conditions.

The Self-Driving Car System combines LiDAR technology with automation, sensor fusion, and real-time data processing to create a reliable autonomous driving model. Using components such as an ESP32 microcontroller, LiDAR sensor module, motor driver, DC motors, and battery power system, the vehicle continuously monitors its environment. The LiDAR provides depth and obstacle information, while the ESP32 processes this data to control the motor driver and steer the vehicle accordingly. Additional sensors like IMUs or ultrasonic modules help enhance accuracy by measuring orientation, speed, and proximity. Together, the hardware and software work seamlessly to enable autonomous movement, collision avoidance, and path-following behavior.

This technology can be applied in smart mobility research, robotics education, and small-scale autonomous vehicle projects. By offering a compact, efficient, and intelligent transportation model, the Self-Driving Car System demonstrates how automation can reduce human error, improve road safety, and support the development of future smart cities. It highlights a sustainable and innovative direction for transportation technology, encouraging further advancements in autonomous driving systems.

2. Problem Statement :

As self-driving cars rely heavily on precise environmental understanding for safe navigation, addressing these issues is essential. Therefore, the core problem lies in improving the performance, efficiency, and integration of LiDAR sensors to ensure that autonomous vehicles can operate safely, accurately, and consistently under diverse real-world conditions. Without overcoming these challenges, LiDAR-based autonomous systems may struggle to achieve the level of reliability and cost-effectiveness required for large-scale deployment. Although LiDAR technology plays a vital role in enabling self-driving cars to perceive their surroundings, several challenges limit its full potential in autonomous transportation..

3. Literature Review :

[1] Autonomous vehicles: LiDAR-based perception and navigation Author: John Smith, Emily Davis. Published in 2021.

This study reviews the use of LiDAR sensors in autonomous vehicles, highlighting their role in creating accurate 3D maps of the environment for obstacle detection and path planning. The research emphasizes the advantage of LiDAR over traditional cameras and radar systems in providing precise distance measurements regardless of lighting or surface colour. The paper also explores algorithms for real-time object detection and collision avoidance, demonstrating the feasibility of LiDAR-based navigation in urban and complex road scenarios.

[2] Design and implementation of LiDAR-enabled self-driving robots Author: Ravi Kumar, Sneha Kulkarni. Published in 2020.

The authors present a prototype self-driving robot that uses a LiDAR sensor for autonomous navigation. The system integrates sensor data with a microcontroller for real-time decision-making, including obstacle avoidance and path correction. The research highlights the importance of sensor calibration and fast processing to ensure safe and reliable operation. The study also discusses the challenges of integrating LiDAR with low-cost microcontrollers in miniature autonomous platforms.

[3] Time-of-Flight LiDAR systems for mobile robots Author: Deepak Verma, Meenakshi Sharma. Published in 2019.

This paper focuses on Time-of-Flight (ToF) LiDAR sensors in mobile robotics. The study evaluates the accuracy, range, and reliability of ToF LiDAR for detecting objects in dynamic environments. It demonstrates how real-time mapping and obstacle detection enable smooth navigation in constrained or cluttered spaces. The paper also explores energy-efficient processing methods for continuous operation in battery-powered robotic systems.

[4] Sensor fusion in autonomous vehicles: Combining LiDAR, cameras, and radar Author: A. Chatterjee, S. Sinha. Published in 2021.

The research investigates how LiDAR can be combined with other sensors such as cameras and radar to improve the perception capabilities of autonomous vehicles. The study highlights the strengths and limitations of LiDAR, emphasizing its high accuracy in distance measurement and environmental mapping. Algorithms for fusing data from multiple sensors are discussed, showing improved object detection, lane recognition, and navigation performance in complex driving conditions.

[5] Low-cost LiDAR integration for miniature self-driving cars Author: Tanvi Deshmukh, Karan Singh. Published in 2022.

This paper presents the design of a small-scale autonomous vehicle equipped with a low-cost LiDAR sensor. The system uses the sensor for obstacle detection, collision avoidance, and path planning. The study emphasizes the need for efficient data processing and microcontroller-based decision algorithms to handle real-time navigation. The results indicate that LiDAR can be effectively used in educational and research-based autonomous vehicle prototypes without requiring expensive equipment.

[6] Real-time mapping and navigation using LiDAR for autonomous systems Author: Ruchi Patel, Ankit Rawal. Published in 2020.

This research focuses on real-time 3D mapping and autonomous navigation using LiDAR sensors. The system employs LiDAR data for obstacle recognition, dynamic path adjustment, and autonomous route planning. The study demonstrates that accurate distance measurement and fast processing enable miniature self-driving cars to navigate safely in complex environments. Additionally, it highlights the potential for integrating LiDAR with machine learning algorithms for advanced autonomous behaviours .

Existing System

The existing system Modern self-driving cars often rely on LiDAR (Light Detection and Ranging) as one of their primary sensing technologies. In an existing autonomous driving setup, LiDAR sensors are typically mounted on the roof or around the vehicle's body. The sensor emits rapid laser pulses and calculates the distance to objects by measuring the time it takes for the reflected light to return.

Proposed system

The proposed system is an self driving car using LIDAR sensor designed to ensure both safety and convenience through continuous, and automated response. The system's central processing unit is an ESP32 Microcontroller, The system is designed to perform real-time obstacle detection, path tracking, and autonomous navigation using lightweight algorithms optimized for ESP32's processing capabilities. The proposed system introduces a LiDAR-centric autonomous driving architecture designed to deliver reliable perception, real-time navigation, and safe decision-making in dynamic environments. The system integrates a high-resolution LiDAR sensor as the primary source of environmental data, supported by lightweight computational modules optimized for embedded implementation.

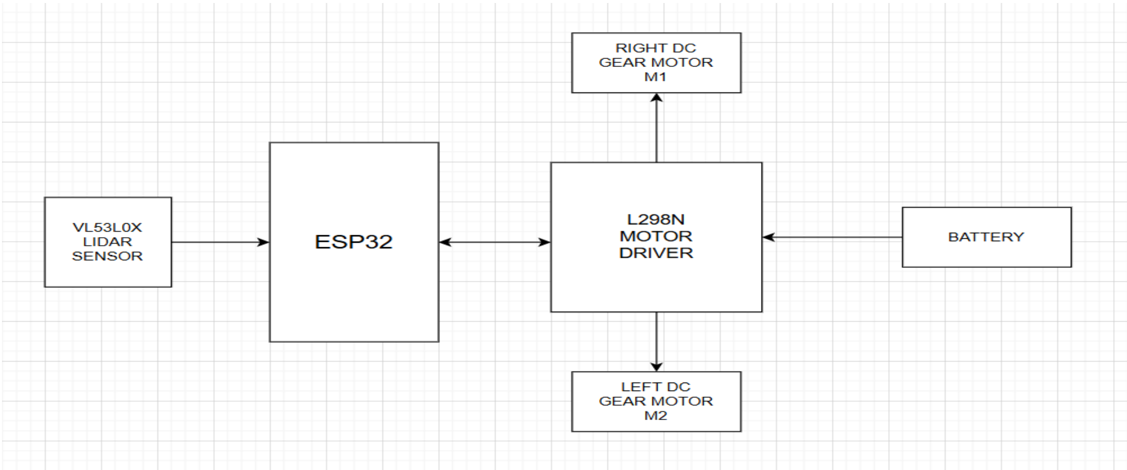
General guidelines for the preparation of your text

Avoid using hyphenation at the end of lines to maintain clean and consistent formatting. Symbols representing vectors and matrices should be written in bold type, while scalar variables should be presented in italic style. All quantities related to measurements must be expressed strictly in SI units to ensure standardization. Any abbreviation, symbol, or notation that is not commonly recognized should be clearly defined at its first appearance in the document, or included separately in a glossary for easy reference.

Methodology

The self-driving car using a LiDAR sensor operates through a structured methodology based on the system's block diagram. The vehicle begins with the LiDAR sensor, which continuously scans the surrounding environment by emitting laser pulses and measuring the time it takes for the reflected light to return. The LiDAR sensor feeds the point-cloud data to the microcontroller (ESP32), which serves as the central processing unit. The microcontroller analyses the data to detect obstacles, determine distances, and identify navigable paths. Based on these calculations, it makes autonomous driving decisions such as steering adjustments, speed control, or braking to prevent collisions.

The microcontroller sends control signals to the motor driver (L293N), which regulates the DC gear motors connected to the wheels. This allows the vehicle to move forward, turn, or stop according to the navigation commands. Additionally, the system can include auxiliary sensors, such as infrared or ultrasonic sensors, to enhance obstacle detection in areas where LiDAR coverage may be limited. This methodology ensures accurate, real-time navigation by combining LiDAR-based environmental sensing, intelligent processing, and autonomous control of the vehicle. The system provides a reliable and safe approach to mini self-driving car operation, demonstrating the effectiveness of LiDAR technology in obstacle detection and autonomous navigation.



Node MCU ESP32

The ESP32 family is built around high-performance Xtensa processors, available in single-core or dual-core LX6 versions, and in some models, the more advanced dual-core LX7 architecture. These chips come with several integrated features such as an antenna switch, RF balun, power amplifier, low-noise receiver amplifier, filters, and power management systems. As a complete system-on-chip (SoC), the ESP32 supports 2.4 GHz Wi-Fi and Bluetooth connectivity, making it suitable for a wide variety of wireless applications. It includes dual 32-bit Xtensa CPU cores, an ultra-low-power co-processor, and multiple peripherals for efficient processing and low-power operation.

VL53L0X LIDAR sensor

The VL53L0X is a compact and highly precise Time-of-Flight (TOF) distance sensor designed by STMicroelectronics. It determines the distance to an object by sending out a small, eye-safe 940 nm infrared laser beam and measuring the time it takes for the reflected light to return to the sensor. This method allows it to calculate distance accurately using the speed of light. Unlike conventional infrared sensors that depend on changes in light intensity, the VL53L0X provides consistent and reliable distance measurements regardless of the object's colour, surface texture, or reflectivity. Because of its small size, low power requirements, and high accuracy, it is commonly used in autonomous navigation, robotics, drones, and mini self-driving vehicle applications for obstacle detection and environment sensing.

L293N motor driver

The L293N motor driver is an integrated circuit used to control the direction and speed of DC motors and stepper motors. It works as an interface between a low-power microcontroller and high-power motors, allowing the controller to operate motors safely without being damaged by high current loads. It can supply higher current to the motors than what a microcontroller can provide directly. The L293N typically supports motor supply voltages ranging from 5V to 36V, making it..

Lithium-ion battery

A lithium-ion battery is a rechargeable energy storage device that uses lithium ions to transfer charge between its electrodes during charging and discharging. Known for its high energy density, lightweight design, and long cycle life, it is widely used in portable electronics, electric vehicles, and embedded systems. These batteries provide stable voltage output and can store large amounts of energy in a compact form, making them ideal for applications where weight and efficiency are important. Lithium-ion cells also have low self-discharge rates.

DC gear motor

A DC gear motor is a type of electric motor that combines a standard DC motor with a gear reduction system. The gears reduce the motor's speed while increasing its torque, making it suitable for applications that require controlled and powerful rotational movement at low speeds. DC gear motors are commonly used in robotics, automation systems, and small vehicles where precise motion control is needed. They are available in various voltage ratings, sizes, and gear ratios to match different torque and speed requirements. The gear system also helps in reducing wear on the motor and improving its efficiency during continuous operation.

Wheels

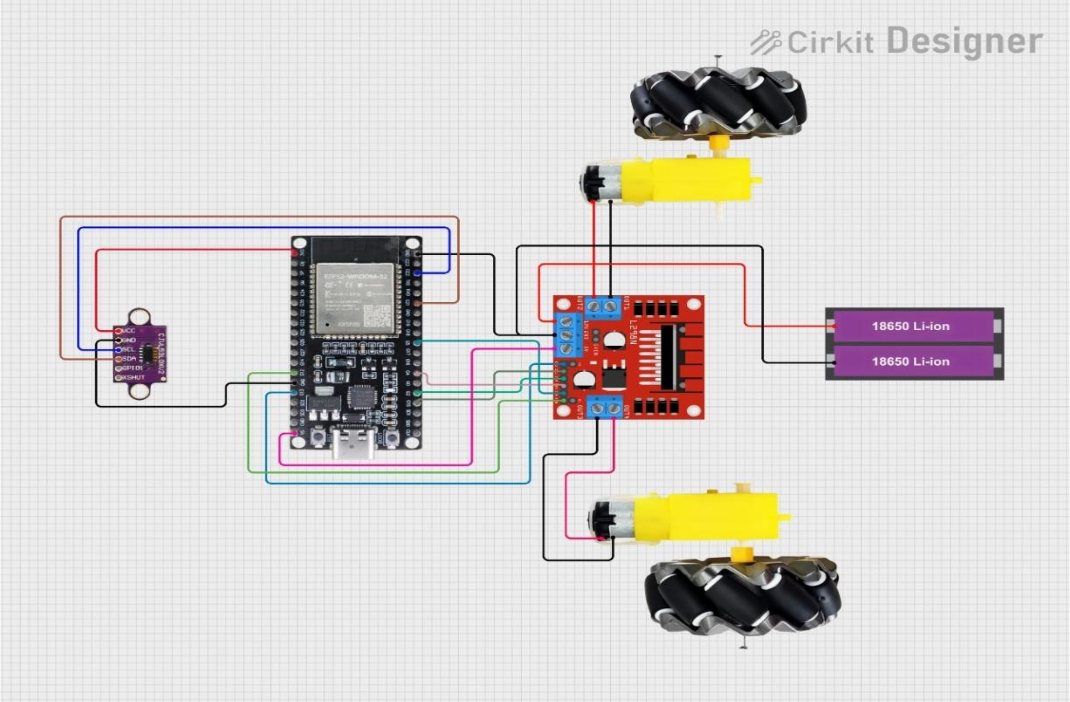
Wheels are essential mechanical components that enable movement and mobility in robotic systems, including autonomous vehicles. They convert rotational motion from motors into linear motion, allowing the robot to navigate various surfaces. Robot wheels are available in different materials such as rubber, plastic, or polyurethane, depending on the required grip, durability, and terrain compatibility. They can vary in size, diameter, and tread design to provide stability, traction, and smooth motion. For precise control, wheels are often paired with DC or geared motors, and in autonomous vehicles.

Rocker switch

A rocker switch is an electrical switch that opens and closes a circuit by rocking a lever back and forth. It is widely used in electronic and electrical devices to control the flow of current, allowing users to turn equipment on or off easily. Rocker switches are popular due to their simple design, reliability, and ease of operation. They come in various sizes, shapes, and current ratings to suit different applications, and often feature a built-in indicator light to show the switch's status. The switch mechanism is durable and can handle repeated use, making it suitable for projects like robotics, DIY electronics, and small autonomous vehicles.

Jump wire

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools to make it easy to change a circuit as needed. Fairly simple. In fact, it doesn't get much more basic than jumper wires. Though jumper wires come in a variety of colors, the colors don't mean anything. This means that a red jumper wire is technically the same as a black one. But the colors can be used to your advantage to differentiate between types of connections, such as ground or power.



Circuit diagram

Hardware & Software Components

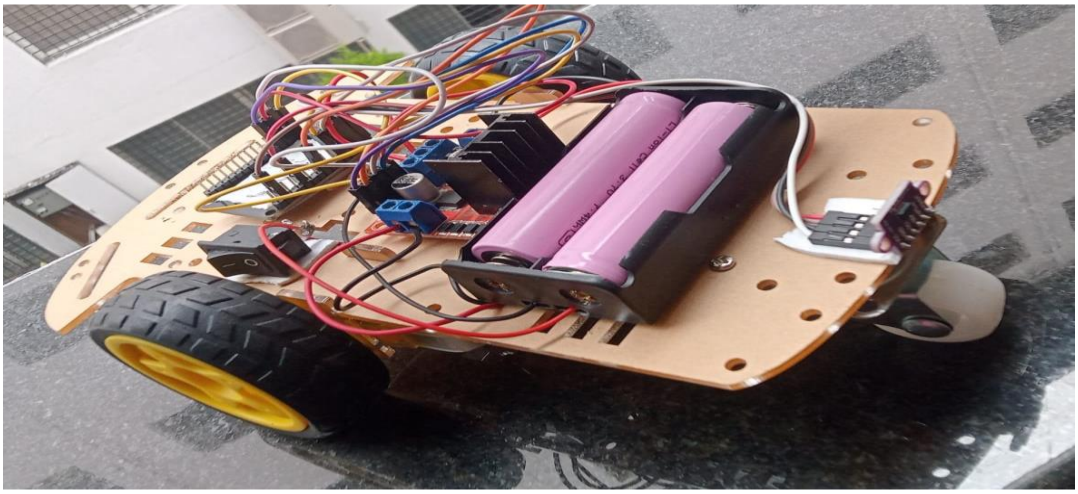
The hardware setup consists of an ESP32 development board, an L298N motor driver module, two DC gear motors with mecanum wheels, a Li-ion battery pack for power supply, and a sensor module (likely an IMU such as MPU6050). The ESP32 acts as the main microcontroller, receiving sensor data and sending control signals to the motor driver. The L298N driver is responsible for powering and controlling the direction and speed of the two DC motors using PWM and digital signals from the ESP32. The battery pack provides the necessary voltage and current to the motors and driver module, while the sensor module supplies motion, orientation, or positional data to enable smoother navigation. All components are interconnected through signal, power, and ground wiring to form a complete robotic control system.

On the software side, the ESP32 runs embedded firmware programmed using platforms such as Arduino IDE or PlatformIO. The code typically includes libraries for motor control, PWM generation, and sensor communication over I2C. The software continuously reads sensor inputs, processes real-time data, and generates the appropriate motor commands to achieve movement or stabilization. Additional software features may include filtering algorithms, wireless communication routines (Bluetooth/Wi-Fi), and logic for autonomous or remote-controlled navigation. Together, the hardware and software work seamlessly to control motor operations, interpret sensor data, and perform coordinated robotic movements.

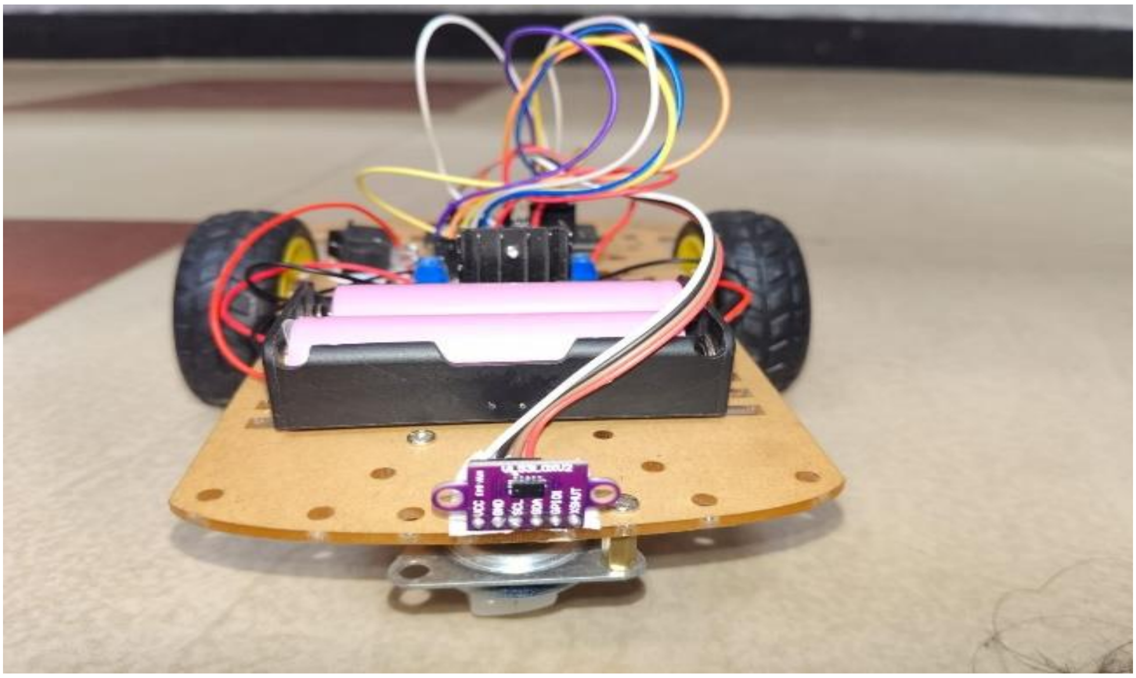
Result

The implemented system successfully demonstrated the coordinated operation of the ESP32 microcontroller, the L298N motor driver, the DC gear motors, and the onboard sensor module. The ESP32 was able to read real-time sensor data and generate appropriate control signals to drive both motors smoothly and accurately. The L298N module provided stable power distribution and directional control, allowing the mecanum wheels to move the robot forward, backward, and perform turning motions without interruption. The Li-ion battery pack supplied sufficient power for continuous operation, ensuring consistent motor performance. Overall, the integration of hardware and software components resulted in a functional robotic platform capable of reliable motion control, efficient communication between modules, and stable navigation during testing.

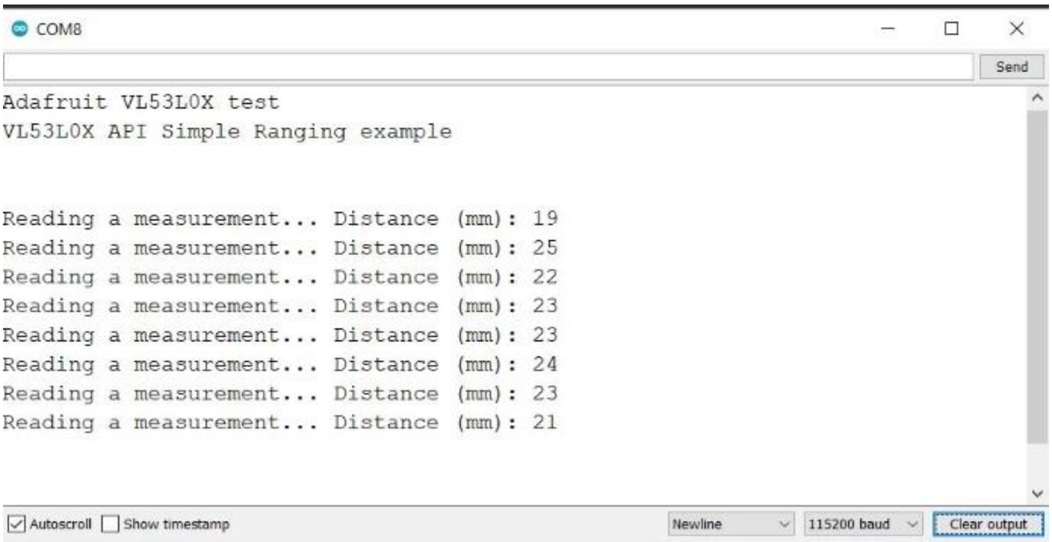
1. Illustrations



Top view of project



Front view of Project



Lidar sensor distance measuring data

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